FIGURE 1

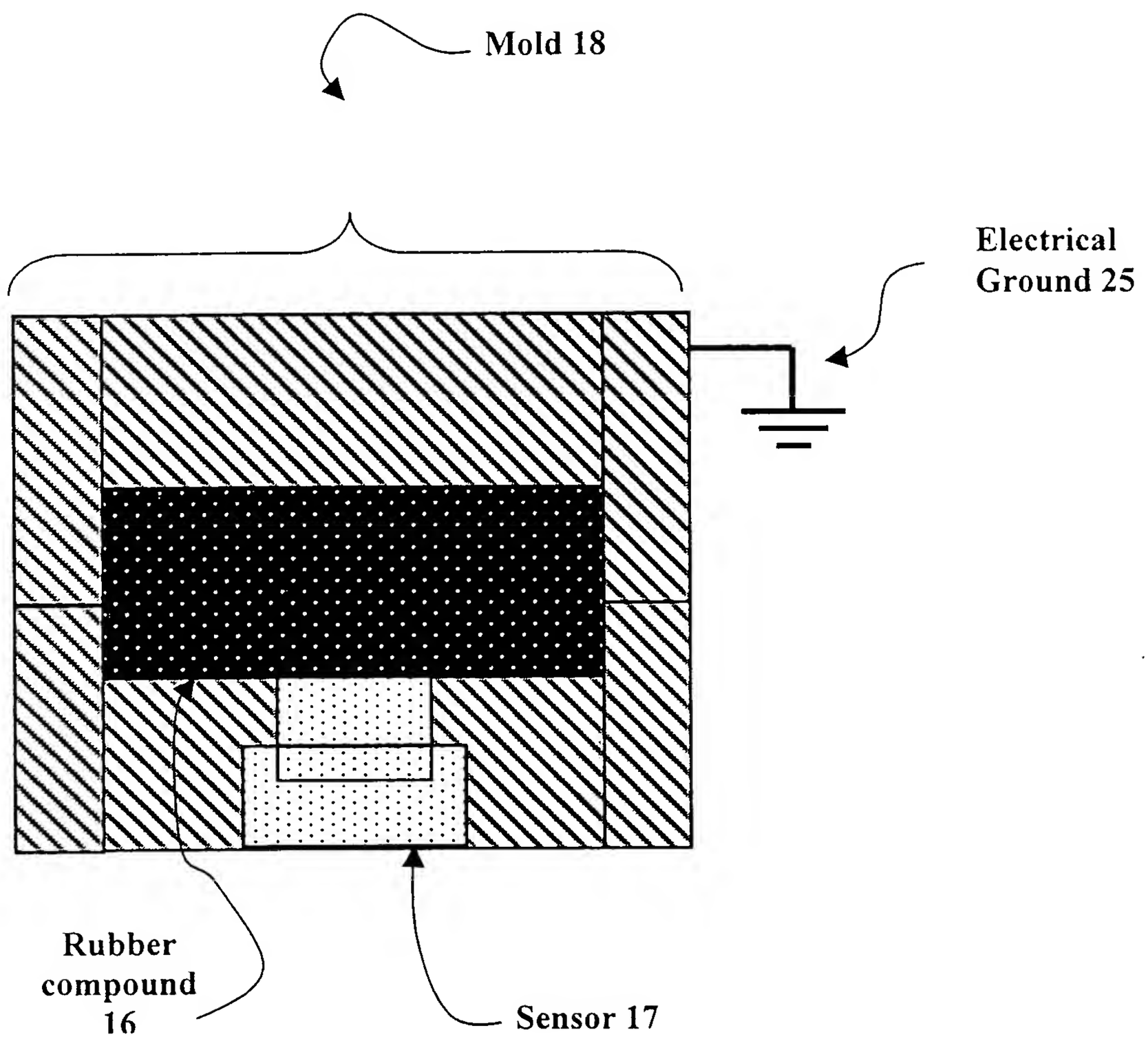


FIGURE 2

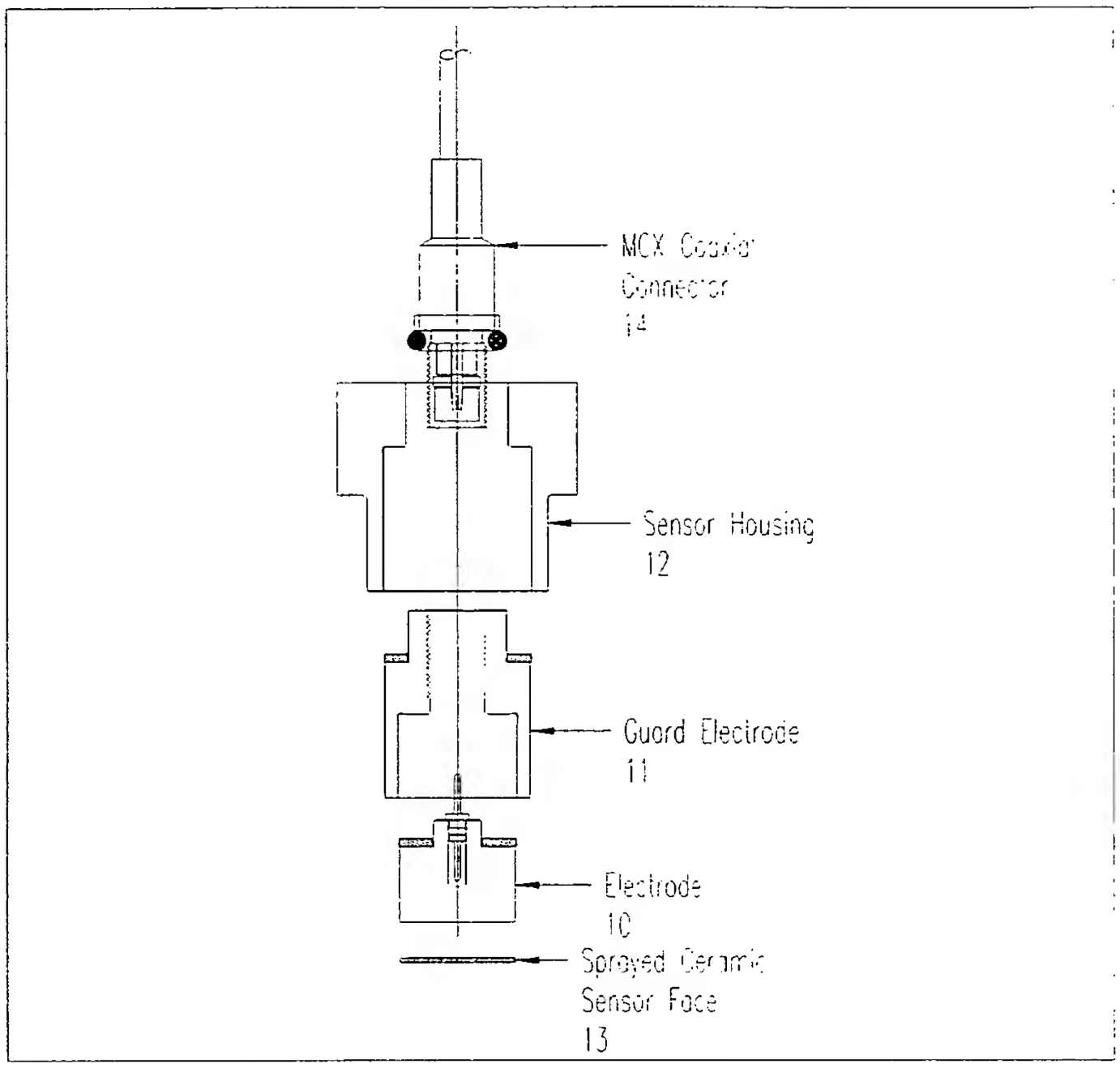

MCX Coaxial
Connector
14
Sensor Housing
12
Guard Electrode
11
Electrode
10
Sprayed Ceramic
Sensor Face
13

FIGURE 3

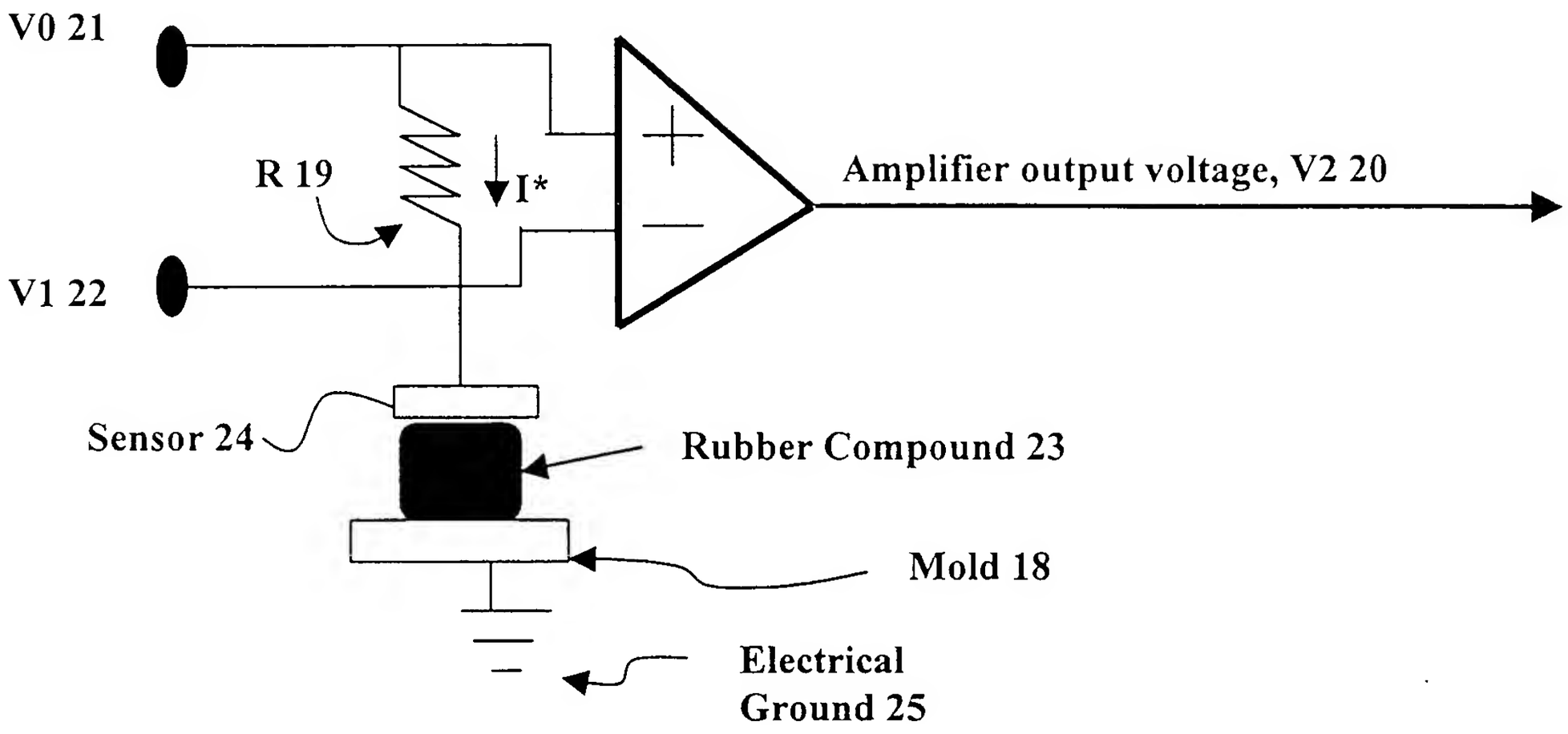

V0 21
R 19
I*
Amplifier output voltage, V2 20
V1 22
Sensor 24
Rubber Compound 23
Mold 18
Electrical
Ground 25

FIGURE 4

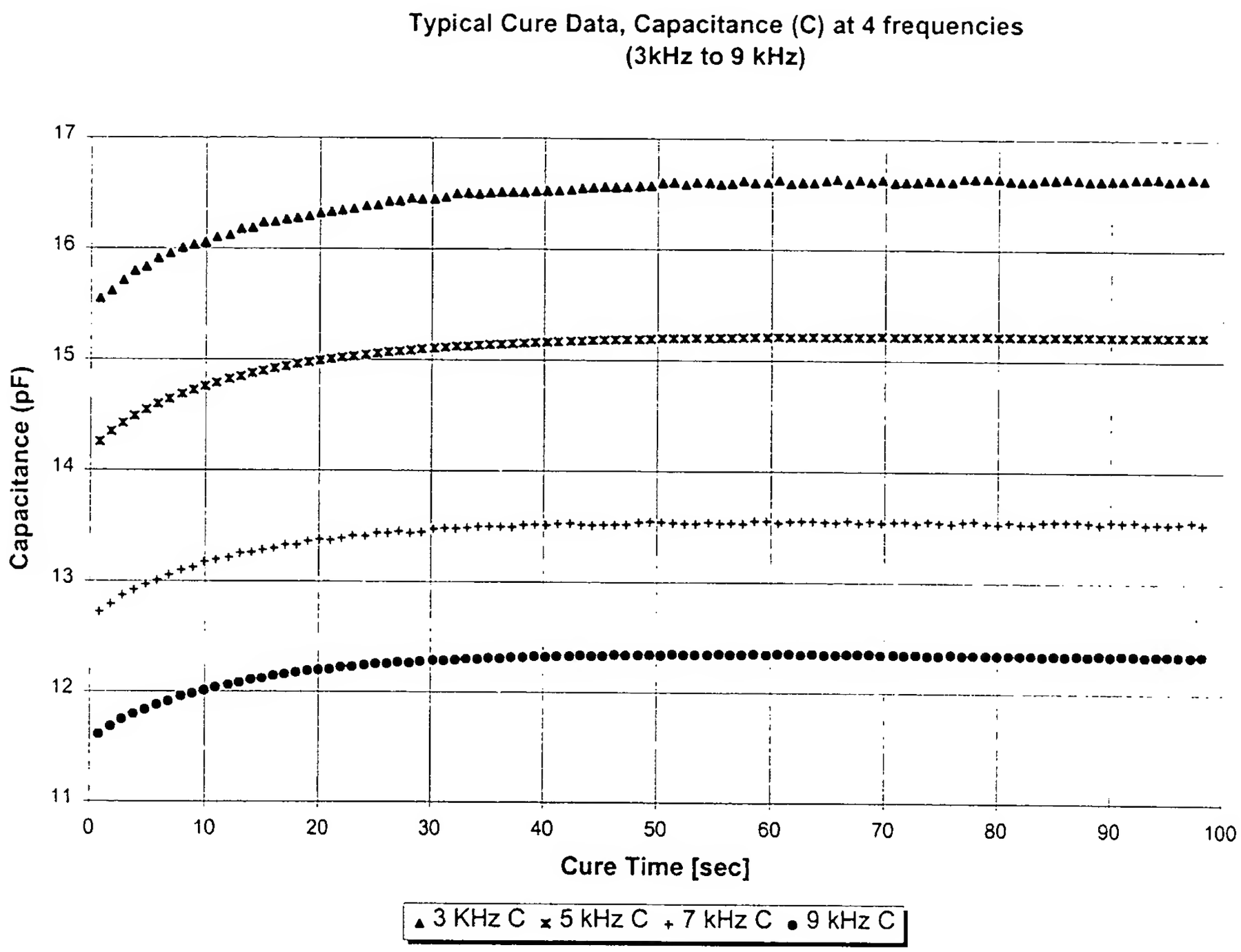

Typical Cure Data, Capacitance (C) at 4 frequencies
(3kHz to 9 kHz)
Capacitance (pF)
17
16
15
14
13
12
11
0
10
20
30
40
50
60
70
80
90
100
Cure Time [sec]
3 KHz C
5 kHz C
7 kHz C
9 kHz C

FIGURE 5

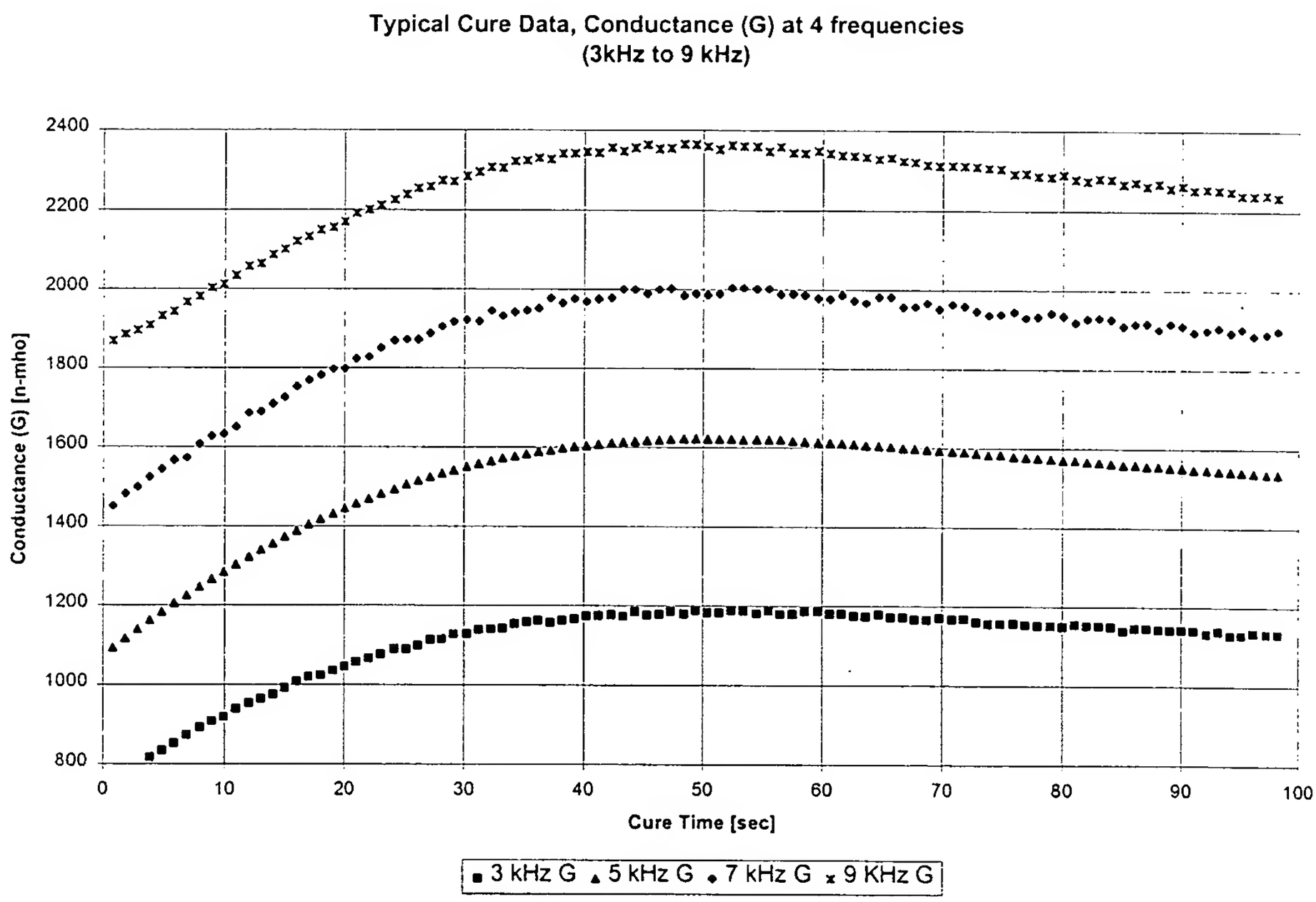
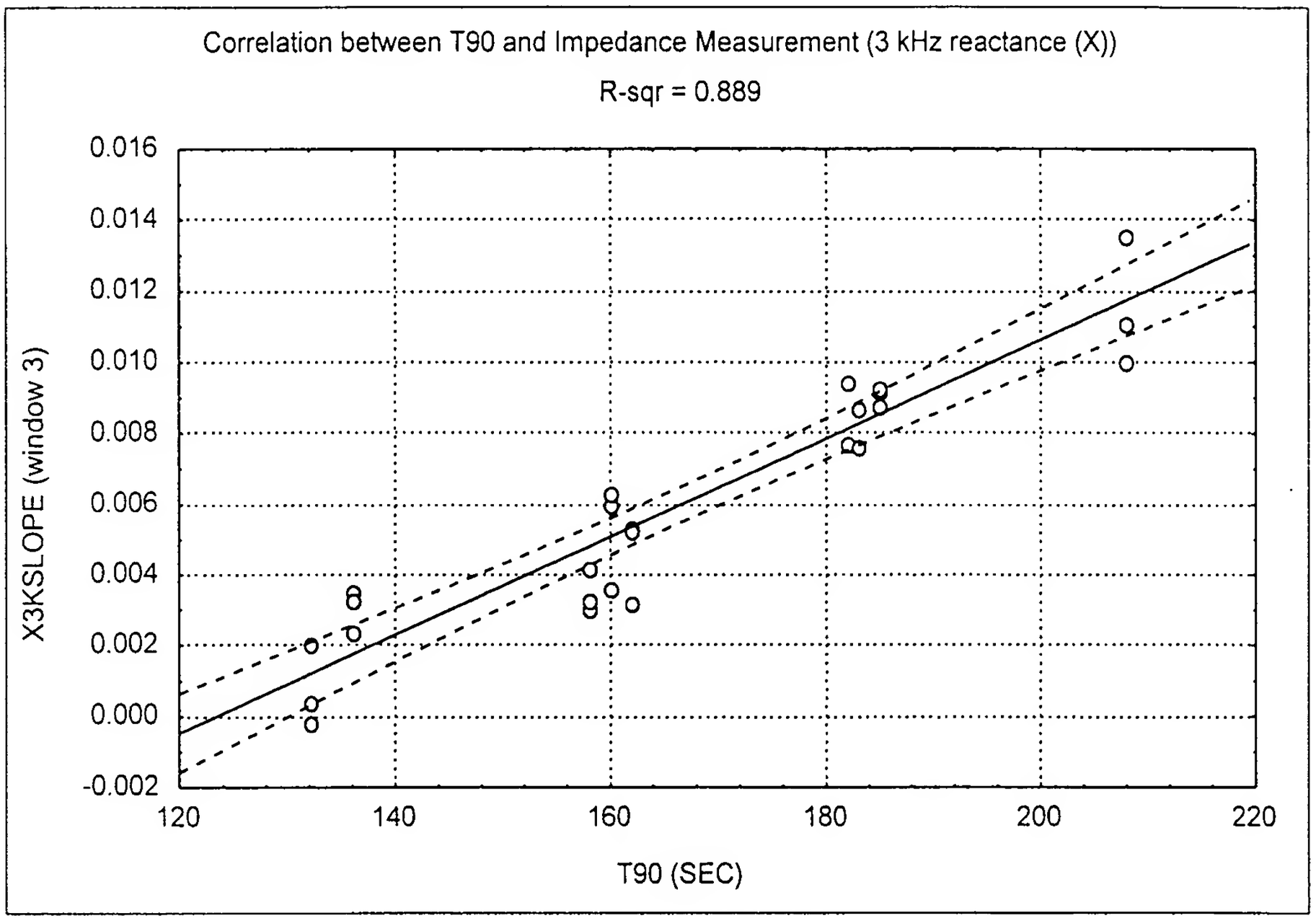

Typical Cure Data, Conductance (G) at 4 frequencies
(3kHz to 9 kHz)
Conductance (G) [n-mho]
2400
2200
2000
1800
1600
1400
1200
1000
800
0
10
20
30
40
50
60
70
80
90
100
Cure Time [sec]
3 kHz G
5 kHz G
7 kHz G
9 KHz G

FIGURE 6



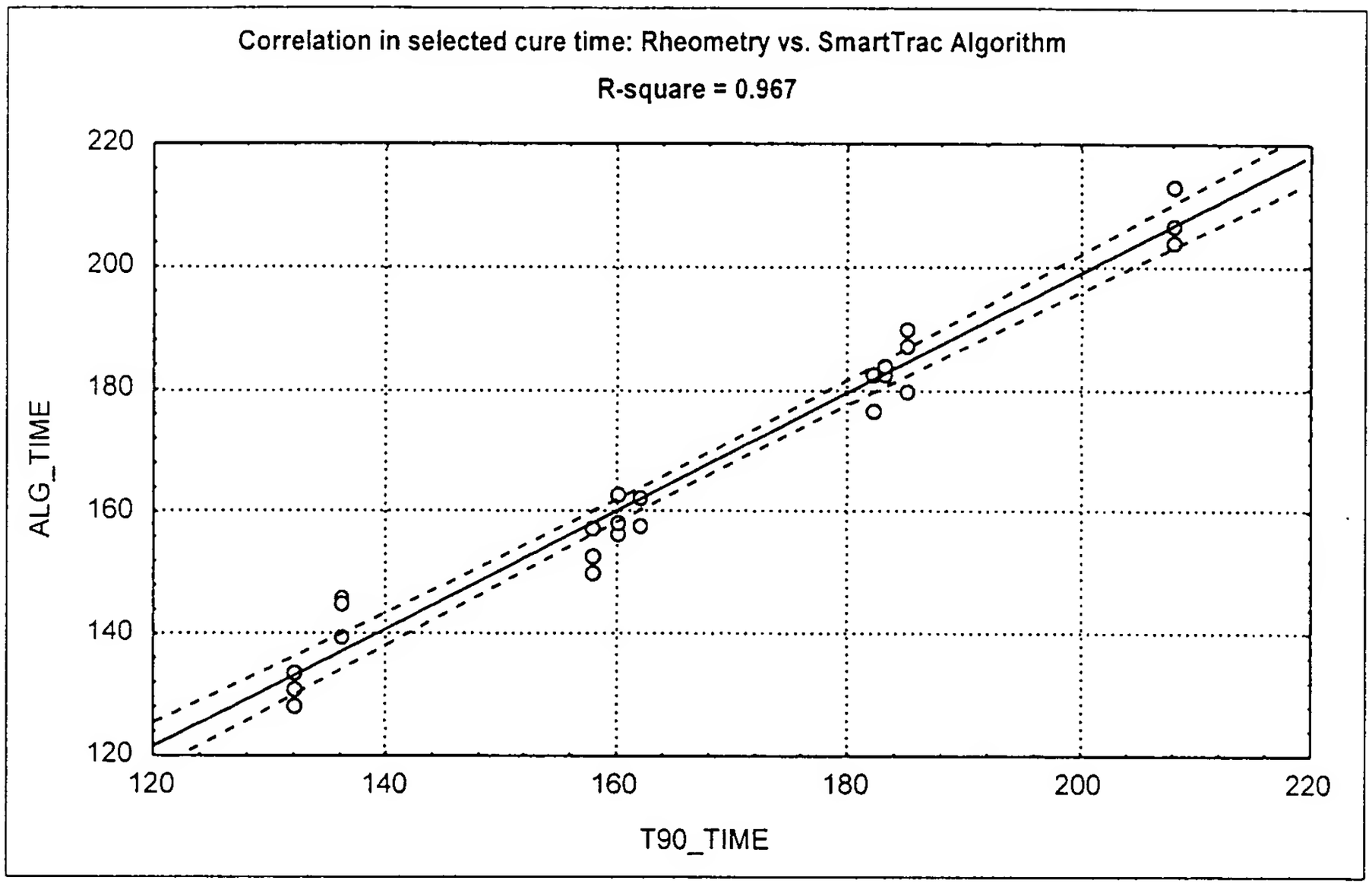
LEGEND:

o Data Point (intersection of algorithm determined time with rheometrically determined cure time.

—— Best Fit through the Data Points

..... 95% Confidence Intervals

FIGURE 7



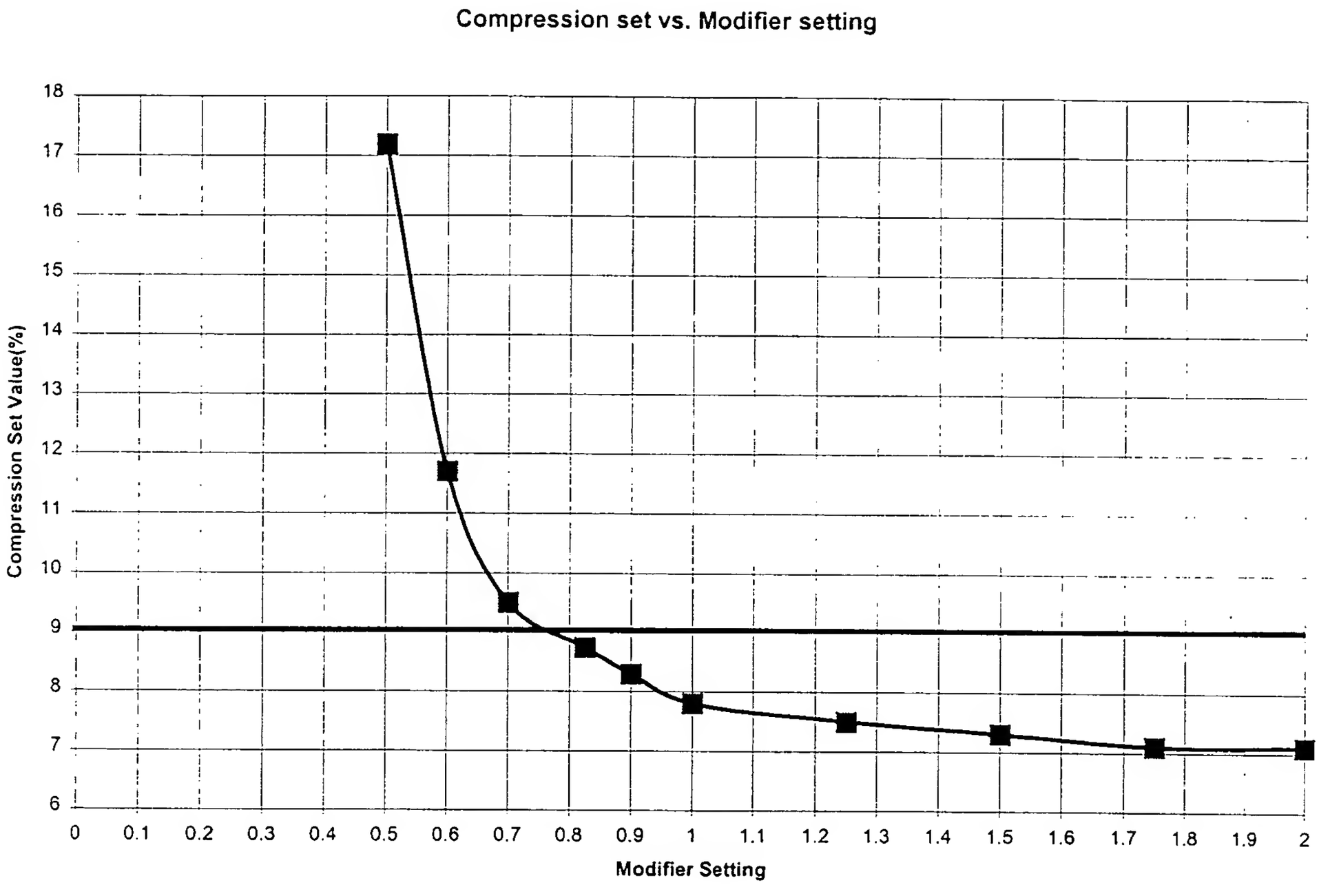
LEGEND:

o Data Point (intersection of algorithm determined time with rheometrically determined cure time.

—— Best Fit through the Data Points

..... 95% Confidence Intervals

FIGURE 8


Compression set vs. Modifier setting
Compression Set Value(%)
18
17
16
15
14
13
12
11
10
9
8
7
6
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2
Modifier Setting

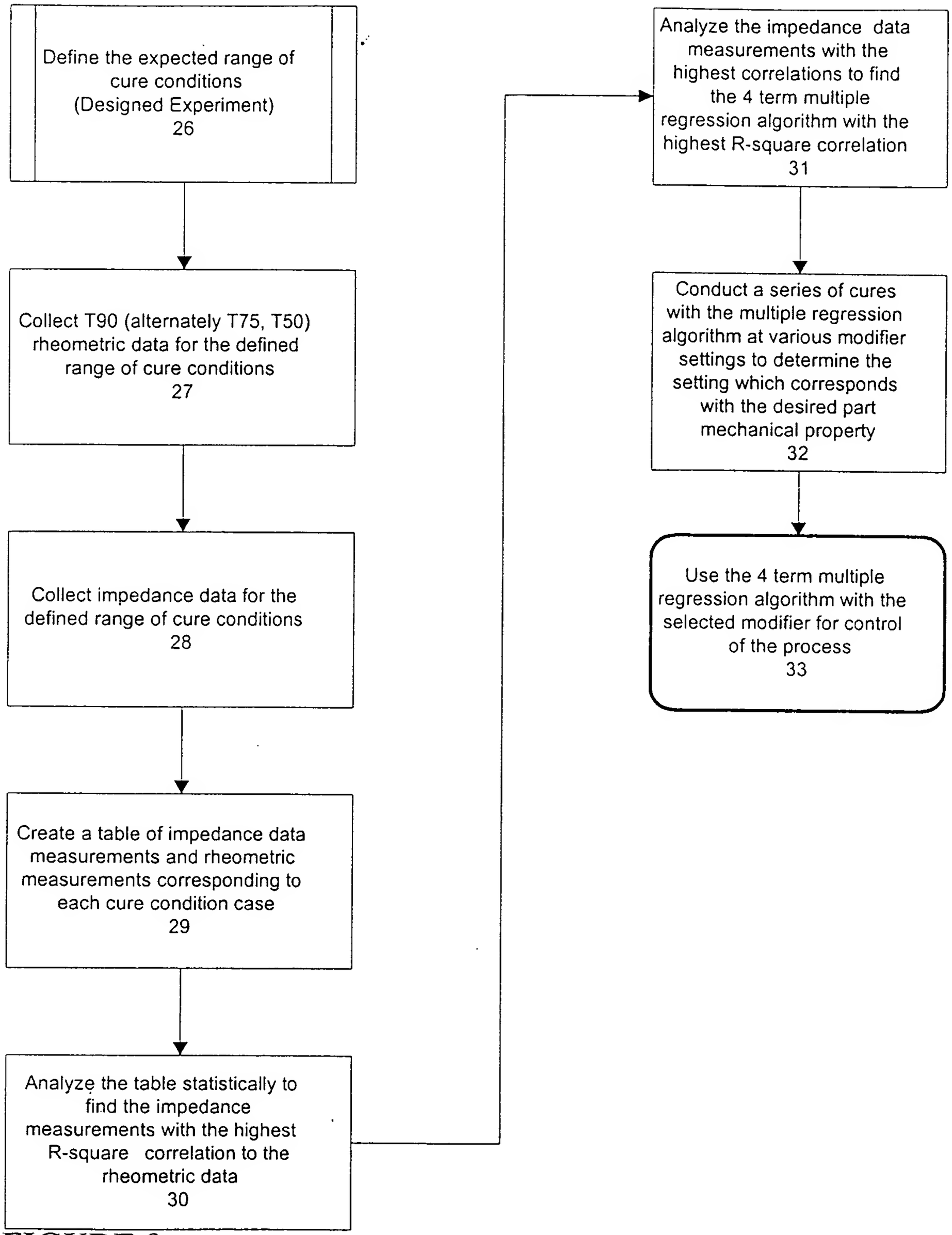
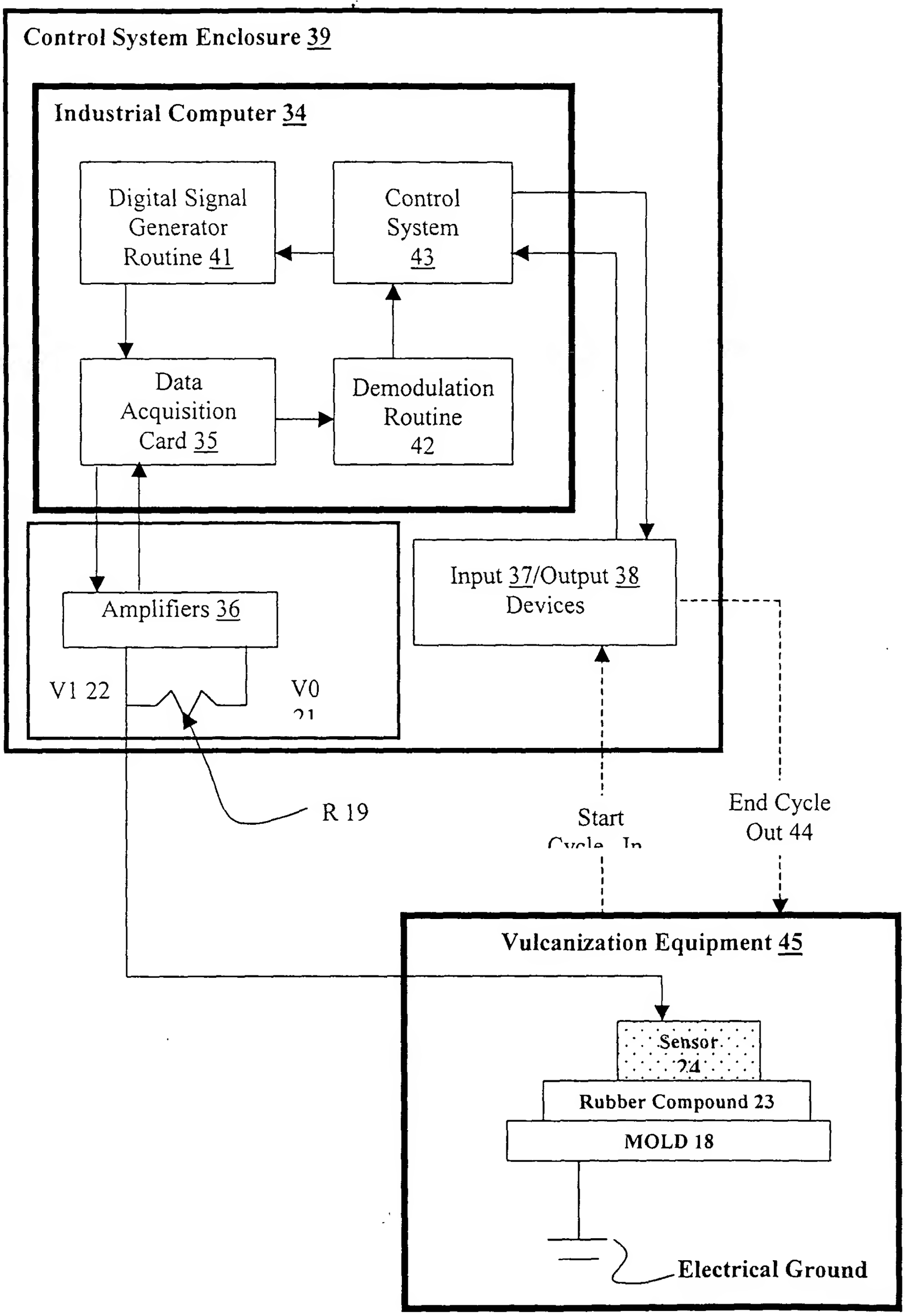

Define the expected range of cure conditions (Designed Experiment) 26
Collect T90 (alternately T75, T50) rheometric data for the defined range of cure conditions 27
Collect impedance data for the defined range of cure conditions 28
Create a table of impedance data measurements and rheometric measurements corresponding to each cure condition case 29
Analyze the table statistically to find the impedance measurements with the highest R-square correlation to the rheometric data 30
Analyze the impedance data measurements with the highest correlations to find the 4 term multiple regression algorithm with the highest R-square correlation 31
Conduct a series of cures with the multiple regression algorithm at various modifier settings to determine the setting which corresponds with the desired part mechanical property 32
Use the 4 term multiple regression algorithm with the selected modifier for control of the process 33

FIGURE 9

FIGURE 10


Control System Enclosure 39
Industrial Computer 34
Digital Signal Generator Routine 41
Control System 43
Data Acquisition Card 35
Demodulation Routine 42
Amplifiers 36
V1 22
V0
Input 37/Output 38 Devices
R 19
Start
End Cycle Out 44
Vulcanization Equipment 45
Sensor 24
Rubber Compound 23
MOLD 18
Electrical Ground

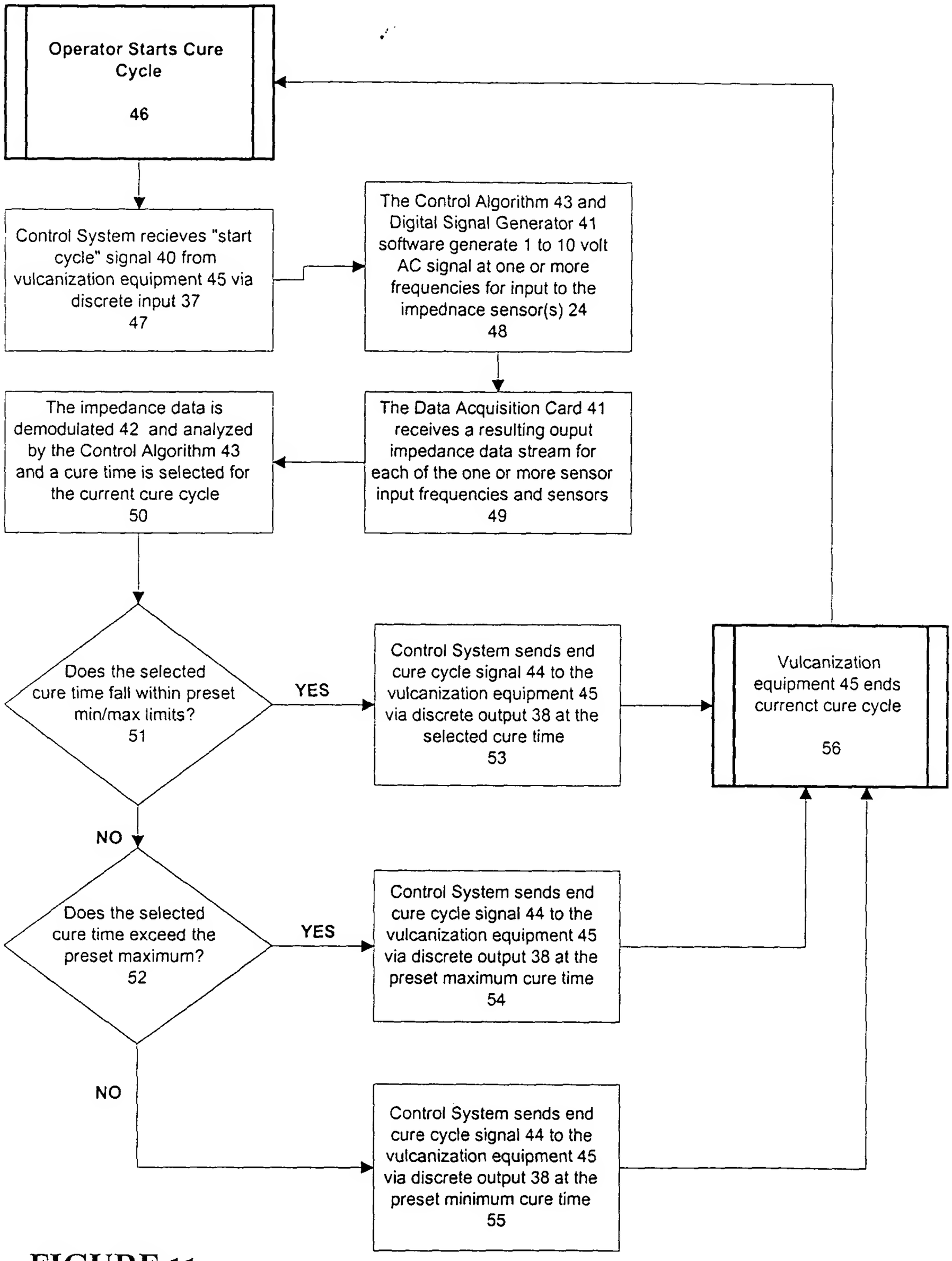

Operator Starts Cure Cycle
46
Control System recieves "start cycle" signal 40 from vulcanization equipment 45 via discrete input 37
47
The Control Algorithm 43 and Digital Signal Generator 41 software generate 1 to 10 volt AC signal at one or more frequencies for input to the impednace sensor(s) 24
48
The Data Acquisition Card 41 receives a resulting ouput impedance data stream for each of the one or more sensor input frequencies and sensors
49
The impedance data is demodulated 42 and analyzed by the Control Algorithm 43 and a cure time is selected for the current cure cycle
50
Does the selected cure time fall within preset min/max limits?
51
YES
Control System sends end cure cycle signal 44 to the vulcanization equipment 45 via discrete output 38 at the selected cure time
53
Vulcanization equipment 45 ends currenct cure cycle
56
NO
Does the selected cure time exceed the preset maximum?
52
YES
Control System sends end cure cycle signal 44 to the vulcanization equipment 45 via discrete output 38 at the preset maximum cure time
54
NO
Control System sends end cure cycle signal 44 to the vulcanization equipment 45 via discrete output 38 at the preset minimum cure time
55

FIGURE 11

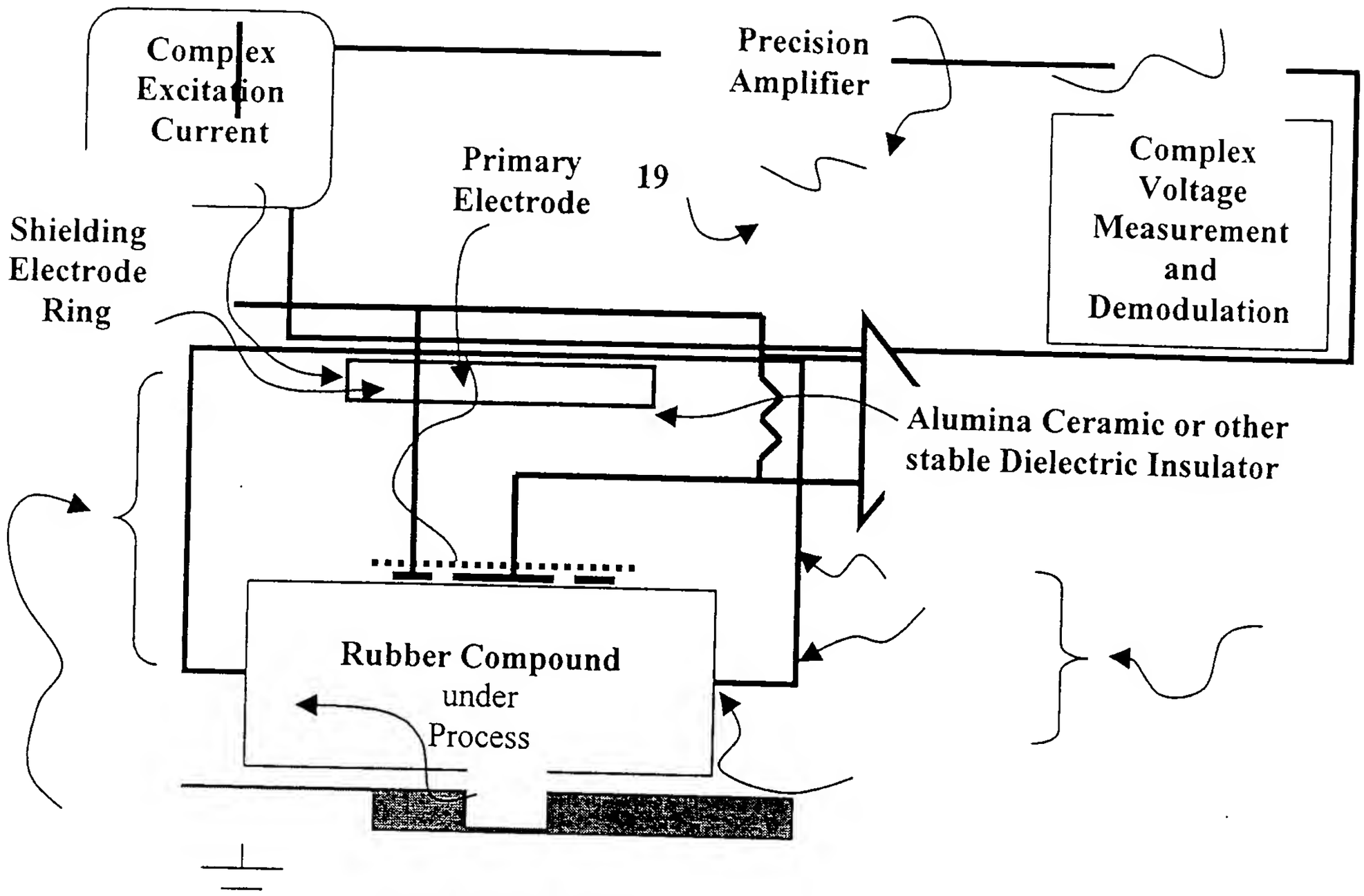

Complex
Excitation
Current
Precision
Amplifier
Primary
Electrode
19
Shielding
Electrode
Ring
Complex
Voltage
Measurement
and
Demodulation
Alumina Ceramic or other
stable Dielectric Insulator
Rubber Compound
under
Process
Vulcanization
Process Ground
Plane (i.e. tool,
mandrel, platen,
opposing mold

FIGURE 12